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Tephrosia purpurea, the potential nectar source for the butterflies in Jodhpur, an arid zone of Thar Desert, Rajasthan, India

Abstract

Observations of plant-insect interactions in the Jodhpur, an extreme arid zone of Thar Desert, Rajasthan have been supported by photographic evidence. The research focused on plant taxa: *Tephrosia purpurea* subsp. *purpurea* and *T. purpurea* subsp. *apollinea* belonging to the Fabaceae family. A total of 26 butterflies belonging to the families Hesperiiidae (Skippers), Lycaenidae (Blues), Nymphalidae (Brush-footed Butterflies), Papilionidae (Swallowtails) and Pieridae (Whites and Yellows) have been recorded here. It was found that these two plants were a major source of nectar, being a part of the diet, and they were larval host plants. In the study area, these butterflies visited other desert plant species. However, these observations explain the importance of these two native taxa of plants for the conservation of pollinators in the arid zones of the country.

Keywords: Biodiversity, cross-pollination, environment, flowers, nectar guides, pollinators

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Introduction

Butterflies are one of the largest taxonomically group of insects (Lepidoptera: Rhopalocera) in the world. They are the indicators of a healthy environment, help in cross-pollination, and natural propagation and are a critical group in ecology and biodiversity conservation. They are also the most plant-dependent group of insects, in which immature stages feed on specific host plant foliage, and adult butterflies feed nectar as their diet (Mac, Fleishman, 2004). The majority of angiosperms are pollinated by insects, mainly bees and butterflies. Most of 80% of terrestrial plants are pollinated by them (Ollerton et al., 2011). The relationship between butterflies and plants is very specific,

the bright colour flowers and nectar guides on petals attract the pollinators. Butterflies are also part of the food chain by being important food sources for many creatures, especially birds and reptiles. Habitat loss, climate change, pesticide usage, change in distribution patterns and diversity of the larval host plants could have resulted in varied changes in the occurrence of butterflies which may result in varied conservation measures. Additionally, seasonal variation probably reflects the phenology of their host and nectar food plants, which also has a huge impact on butterfly species diversity.

Till the 18th century about 19,238 species of butterflies have been documented worldwide (Heppner, 1998). About 1,501 species of butterflies have been reported from India (Kunte, 2000), and 1431 species have been recorded in the Indian Foundation of Butterflies (Kunte et al., 2023). The butterfly fauna of Western India, mainly arid zones of Rajasthan were extensively studied by MacPherson (1927), followed by Talbot (1939, 1947), Mathur, Champakavalli (1961), Gupta, Thankur (1986) and Kunte (2000). Kazmi et al. (2003), reported 39 species of butterflies from the desert regional station, Jodhpur district of Rajasthan. Recent records of 94 species were reported from Rajasthan (*iNaturalist*, 2023).

Butterflies also play an important role in pollinating plants associated with extremely unfavorable habitat conditions. This type of habitat includes, among others, deserts and semi-deserts. For example, among the plants in the desert and fallow lands of Jodhpur (Rajasthan, India), the bright pinkish flowers of *Tephrosia purpurea* subsp. *purpurea* (L.) Pers. and *T. p.* subsp. *apollinea* (Delile) Hosni & El-Karemy attract many butterflies and offer nectar to them. *T. purpurea* (wild indigo, purple tephrosia, fish poison) is a species of flowering plant in the family Fabaceae, with a tropical distribution. It is an erect or spreading annual or short-lived perennial herb, sometimes bushy, 40–80 cm tall, rarely up to 1.5 m; stem slender, erect or decumbent at base. Leaves imparipinnate; leaflets 5–25, obovate to narrowly elliptical, terminal leaflet 7–28 mm × 2–11 mm, lateral leaflets 5–30 mm × 2–11 mm, acute at base, apex rounded to emarginate, venation usually distinct on both surfaces.

Inflorescence an axillary or leaf-opposed pseudo-raceme, (1.5–) 10–15(–25) cm long, sometimes with basal leaf-like bracts; flowers in fascicles of 4–6; *corolla* is purplish to white; *calyx* campanulate, persistent, unequally 4-toothed, teeth pubescent inside (Singh, 1987).

T. purpurea is a very variable species. Most characteristic is the shape of its pod: convex around the seeds with a distinctive flat area in between (Fig. 1). For South-East Asia *T. purpurea* is classified as follows: (a) subsp. *barbigera* Bosman & de Haas: vexillary filament and staminal tube velutinous (occurring in the Philippines, New Guinea and Australia); based on flower and inflorescence lengths, further subdivided into 2 varieties: var. *barbigera* (flower 7–8 mm long, longest inflorescence 11–19.5 cm long) and var. *rufescens* Benth. (flower 5–6 mm long, longest inflorescence 4.5–11 cm long);



Fig. 1. Habit, inflorescence and in frutescence of *Tephrosia purpurea* (L.) Pers. A–C. *T. purpurea* subsp. *purpurea* (L.) Pers.; D–F. *T. p.* subsp. *apollinea* (Delile) Hosni & El-Karemy (Photo. Ravi Kiran Arigela)

(b) subsp. *purpurea* (Fig. 1A–C) characteristics as described for the species (vexillary filament and staminal tube glabrous). This subspecies occurs in West Tropical Africa to the Arabian Peninsula and Angola, Comoros, Madagascar, tropical and subtropical Asia to the South Pacific (POWO, 2023). Another subspecies *T. purpurea* (c) subsp. *apollinea* (Fig. 1D–F) have pinnate leaves divided into obovate to oblong, silky-hairy, grey-green leaves. From midwinter to late spring, it has racemes of pea-like purple to purple-pink flowers. Flattened, green seed pods ripening pale brown. It occurs in the following regions: from South Egypt to Chad and from to Arabian Peninsula to Northwest India (POWO, 2023). The flowering of these two plants starts from July and last up to March, but massive blooming is seen between July and September. *T. purpurea* is used as a green manure crop, also used as a fish poison, and has a variety of traditional uses in folk medicine. It is also used as fodder for animals such as goats. Its leaves and seeds contain tephrosin, which paralyzes fish, and larger doses are lethal. Extracts from the plant are also used in certain cosmetic preparations (Bhardwaj, Shrivastava, 2016).

The number of butterflies nectaring on the flowers of *T. purpurea* plant species in the arid zone of Thar Desert, Jodhpur, Rajasthan (India) drew the attention of the authors of this article. Therefore, they undertook explorations aimed at observing the plant-insect interactions (i) and recording the butterflies visiting these plants (ii).

Materials and methods

Study area

The Thar Desert is spread over Rajasthan, Gujarat and Haryana states of India, and covers an area of 259,000 km². The maximum area is covered in Rajasthan, about 3/5th of the 342,239 km² geographical area of the state. Of the total desert in India, 61% falls in Rajasthan, 20% in Gujarat, and 9% in Punjab and Haryana. The Thar Desert covers 10 districts of Rajasthan, namely Barmer, Bikaner, Churu, Hanumanagarh, Jaisalmer, Jalore, Jodhpur, Nagaur, Pali and Sri Ganganagar. Low-elevation hills, dunes and fallow lands are the common landscapes of the Thar Desert of Jodhpur (Reddy et al., 2010). The majority of fallow lands in Jodhpur were occupied by *Aerva javanica* (Burm.f.) Juss. ex Schult., *Calotropis procera* (Aiton) W.T.Aiton, *Cenchrus biflorus* Roxb., *Crotalaria burhia* Buch.-Ham. ex Benth., *Dactyloctenium scindicum* Boiss., *Leptadenia pyrotechnica* (Forssk.) Decne., *Tephrosia purpurea* subsp. *purpurea* and *T. p.* subsp. *apollinea*.

Jodhpur district (Fig. 2B) is one of the largest districts of Rajasthan state with 22850 km² geographical area. It lies between 26°00' and 27°37' North latitude and 72°55' and 73°52' East longitude, and elevations range between 250 to 300 m a.s.l. Extremes high temperatures in summer and low temperatures in winter, very low annual

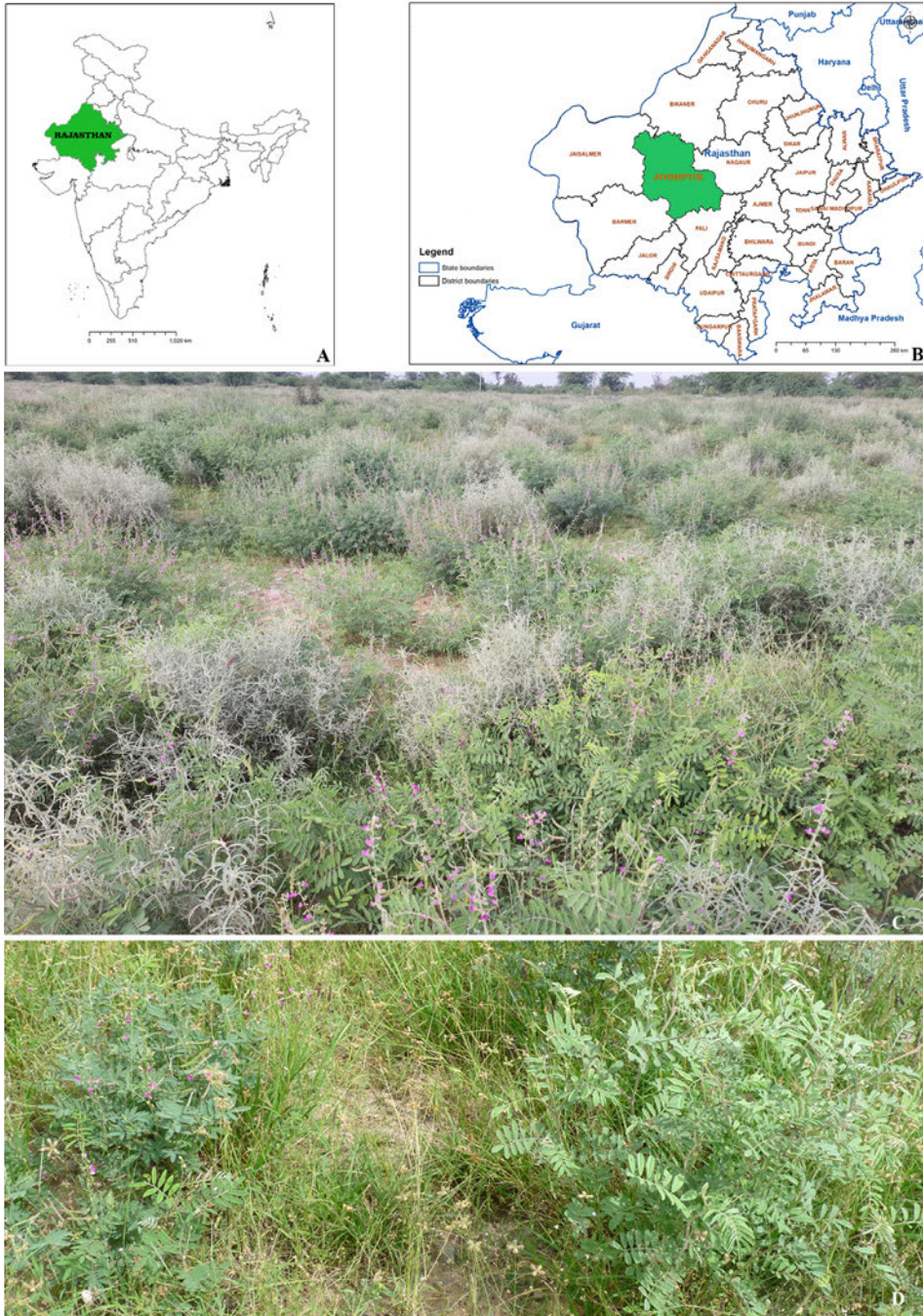


Fig. 2. Study area. A. Rajasthan state, India; B. Jodhpur district of Rajasthan state; C-D. *Tephrosia purpurea* subsp. *purpurea* and *T. purpurea* subsp. *apollinea* growing together in a habitat (Photo. Ravi Kiran Arigela)

precipitation and dryness are the characteristic climate of Jodhpur district. The winter lasts from November to March followed by summer from April to June. The southwest monsoon season lasts from July to mid-September with an average rainfall of 360 mm. The temperature varies from 50°C in summer to 1°C in winter. The terrain is sandy plains, low elevated hills and dunes with sandy and loamy soils. This district comes under the arid zone of the Rajasthan state and covers 11.60% of the total area of the arid zone of the state. Thorn Forest including naturalized thorn plantations, scrub and grasslands are the major vegetation types in Jodhpur (Reddy et al., 2010).

Methodology

Studies on butterflies and their interactions with *Tephrosia purpurea* subsp. *purpurea* and *T. p.* subsp. *apollinea* plants were conducted in the Jodhpur district, Rajasthan. The interactions of butterflies with selected plants were studied and recorded based on direct observations in the field. Regular fortnight surveys were carried out from November 2022 to September 2023 from 7:00 to 11:00 and 16:00 to 18:00 on fixed routes in the landscape, with different zones and adjoining areas using modified “Pollard walk” method (Pollard, 1977; Pollard, Yates, 1993; Royer et al., 1998).

In this study, the authors did not use any fixed transects due to the distribution of plants in one particular place. Observers (RKA, TK, RK, and PKD) recorded butterflies observed within a 5-meter strip around the analysed plants while walking at a slow and steady pace. No insects were collected/ harmed using a trapping net. Species identifications were made visually in the field, sometimes using photographs made by one of the authors being a butterfly expert. Nikon 5300 with Nikkor 200–500 lens, Panasonic FZ–28 digital camera, and Samsung F–62 mobile camera were used to capture the butterflies and plants.

Based on the results, a list of butterfly species was prepared, including families and a short description of the general range of the recorded species, their range and status in India, and plants on which their larvae feed. This characterisation was made based on the available bibliography. Botanical nomenclature WFO (<https://www.worldflora-online.org/>), and for butterflies, *Butterflies of India* (Kunte et al., 2023) and Kehimkar (2016) were followed.

Results

During the investigation we found, a total of 26 butterflies under 20 genera (belongs to five families) (Fig. 3–6 – Appendix 1) collect the nectar from *T. purpurea* subsp. *purpurea* and *T. p.* subsp. *apollinea* in Jodhpur. The family Lycaenidae (blues) contributes seven genera and eight species, followed by Pieridae (whites and yellows) four genera and seven species, Nymphalidae (brush-footed Butterflies) four genera and six species, Hesperiiidae (Skippers) three genera and three species, Papilionidae (swallowtails) two

genera and two species. *Danaus chrysippus* form *dorippus* was also observed in the study (Fig. 5E – Appendix 1). Additionally, eight butterflies of the Lycaenidae (blues) family were noticed and these also collect the moisture (dew) from the spikes (inflorescence) of grass and help in the cross-pollination of millets.

Among the recorded species, three were distributed in the Himalayas and Western India these are as follows *Gegenes pumilio*, *Belenois aurota* and *Colotis vestalis* remaining 22 species were common throughout India. Painted lady *Vanessa cardui* is the only species that migrates from Africa to Asia and it is not rare in India. Apart from *T. purpurea* subsp. *purpurea* and *T. p.* subsp. *apollinea*, the other associated plant species in these habitats also provide the nectar to the listed butterflies. But, all these 26 butterflies do not collect the nectar from the all-associated plants and specific butterflies are visit specific plant species. Name of the host plants and their butterflies are given in the table (1) – Appendix 2.

List and short characteristics of recorded butterfly species nectaring on flowers of *Tephrosia purpurea* subsp. *purpurea* and *T. p.* subsp. *apollinea*

Family: HesperIIDae Latreille – Skippers

1) *Borbo cinnara* (Wallace) – Rice Swift (Fig. 4D – Appendix 1)

General range of occurrence: Sri Lanka, India, Myanmar, Vietnam, Cambodia, Taiwan, Australia (Evans, 1949; Varshney, Smetacek, 2015)

Occurrence and status in India: Common

Host plants of the larvae: *Axonopus compressus* (Sw.) P.Beauv., *Rottboellia cochinchinensis* (Lour.) Clayton, *Setaria barbata* (Lam.) Kunth, and *Urochloa mutica* (Forssk.) T.Q.Nguyen (Kalesh, Prakash, 2007)

2) *Gegenes pumilio* (Hoffmansegg) – Pigmy Skipper (Fig. 4A – Appendix 1)

General range of occurrence: coasts of the Mediterranean Sea; through Anatolia to the Himalaya and south in the whole of Africa (Wynter-Blyth, 1957; Kunte et al., 2023)

Occurrence and status in India: Common in the Himalayas and Western India

Host plants of the larvae: *Cenchrus clandestinus* (Hochst. ex Chiov.) Morrone, *Cynodon* species, *Ehrharta* species (including *Ehrharta erecta* Lam.) (Evans, 1932; Wynter-Blyth, 1957)

3) *Spialia galba* (Fabricius) – Asian Grizzled Skipper (Fig. 5C – Appendix 1)

General range of occurrence: South and Southeast Asia: Sri Lanka, India, to the Shan states in northern Myanmar, Thailand, Vietnam and Hainan (Watson, 1891; Evans, 1932, 1949; Varshney, Smetacek, 2015)

Occurrence and status in India: Very common up to an altitude of 1800 m (Haribal, 1992)

Host plants of the larvae: *Alcea rosea* L., *Glycine max* (L.) Merr., *Hibiscus micranthus* L.f., *Melochia corchorifolia* L., *Sida rhombifolia* L., *Urena lobata* L., *Waltheria indica* L. (Haribal, 1992; Kunte, 2000; Kalesh, Prakash, 2007; Ravikanthachari et al., 2018)

Family: Lycaenidae Leach – Blues butterflies

4) *Azanus ubaldus* (Stoll) – Bright Babul Blue (Fig. 3B – Appendix 1)

General range of occurrence: India, the Middle East and Africa (Woodhall, 2005; Varshney, Smetacek, 2015)

Occurrence and status in India: Common, mostly in lower altitudes and drier places.

Host plants of the larvae: *Acacia leucophloea* (Roxb.) Willd., *A. nilotica* (L.) Willd. ex Delile (Nitin et al., 2018)

5) *Azanus uranus* (Butler) – Dull Babul Blue (Fig. 3D – Appendix 1)

General range of occurrence: India (Varshney, Smetacek, 2015)

Occurrence and status in India: Common and mostly in lower altitudes.

Host plants of the larvae: *Acacia catechu* (L.f.) Willd., *A. farnesiana* (L.) Willd., *A. leucophloea*, *A. nilotica*, *A. senegal* (L.) Willd. (Robinson et al., 2010; Nitin et al., 2018)

6) *Catochrysops strabo* (Fabricius) – Forget-me-not (Fig. 3E – Appendix 1)

General range of occurrence: Asia: Sri Lanka, India, from Sikkim to Indochina, in Sundaland, Sulawesi and the Philippines (Varshney, Smetacek, 2015)

Occurrence and status in India: Common

Host plants of the larvae: *Acacia* sp., *Butea monosperma* (Lam.) Kuntze, *Cajanus cajan* (L.) Millsp., *Desmodium oojeinense* (Roxb.) H. Ohashi, *Flemingia strobilifera* (L.) W.T. Aiton, *Paracalyx scariosus* (Roxb.) Ali, *Pueraria phaseoloides* (Roxb.) Benth., *Pongamia pinnata* (L.) Pierre, *Schleichera oleosa* (Lour.) Oken, *Tephrosia purpurea* (L.) Pers., *Vigna unguiculata* (L.) Walp. (Kunte, 2000; Robinson et al., 2010; Nitin et al., 2018)

7) *Chilades pandava* (Horsfield) – Plains Cupid (Fig. 4C – Appendix 1)

General range of occurrence: South Asia: Myanmar, United Arab Emirates, Indochina, Peninsular Malaysia, Singapore, Taiwan, Java, Sumatra and the Philippines (Varshney, Smetacek, 2015)

Occurrence and status in India: Common

Host plants of the larvae: *Acacia* sp., *Bauhinia* sp., *Butea monosperma*, *Caesalpinia* sp., *Cycas circinalis* L., *C. revoluta* Thunb., *Moullava spicata* (Dalzell ex Wight) Nicolson, *Ougeinia oojeinensis* (Roxb.) Hochr., *Saraca asoca* (Roxb.) Willd., *Schleichera oleosa* (Lour.) Oken, *Xylia xylocarpa* (Roxb.) W.Theob. (Wynter-Blyth, 1957; Kunte, 2000; Robinson et al., 2010; Nitin et al., 2018)

- 8) *Freyeria putli* (Kollar) – Black-spotted Grass Jewel (Fig. 3F – Appendix 1)
 General range of occurrence: Ceylon, Myanmar, India and Australia (von Hügél, 1840; Varshney, Smetacek, 2015)
 Occurrence and status in India: Very common
 Host plants of the larvae: *Crotalaria hebecarpa* (DC.) Rudd, *Heliotropium strigosum* Willd., *Indigofera astragalina* DC., *I. linnaei* Ali, *Lotus corniculatus* L., *Oxalis corniculata* L., *Pisum sativum* L., *Rhynchosia minima* (L.) DC., *Trichodesma indicum* (L.) Lehm., *Vicia* sp., *Zornia diphylla* (L.) Pers. (Robinson et al., 2010; Firoz et al., 2018; Nitin et al., 2018)
- 9) *Leptotes plinius* (Fabricius) – Zebra Blue (Fig. 5B – Appendix 1)
 General range of occurrence: Sri Lanka, India to Australia (Varshney, Smetacek, 2015)
 Occurrence and status in India: Very common
 Host plants of the larvae: *Abrus precatorius* L., *Albizia lebbbeck* (L.) Benth., *Dalbergia lanceolaria* L.f., *Dyerophytum indicum* Kuntze, species of *Indigofera*, *Mimosa pudica* L., *Mimosa hamata* Willd., *Plumbago auriculata* Lam., *P. zeylanica* L., *Sesbania bispinosa* (Jacq.) W.Wight, (Kunte, 2000, 2006; Vane-Wright, de Jong, 2003; Robinson et al., 2010; Nitin et al., 2018; Savela, 2018)
- 10) *Tarucus nara* (Kollar) – Striped Pierrot (Fig. 4G – Appendix 1)
 General range of occurrence: Sri Lanka and south India (Varshney, Smetacek, 2015)
 Occurrence and status in India: Common in lower altitudes
 Host plants of the larvae: *Ziziphus jujuba* Mill., *Z. nummularia* (Burm.f.) Wight & Arn. (Kunte, 2000; Robinson et al., 2010; Bhakare et al., 2018)
- 11) *Zizeeria karsandra* (Moore) – Dark Grass Blue (Fig. 3C – Appendix 1)
 General range of occurrence: southern Mediterranean, in India, Sri Lanka, the Andaman and Nicobar Islands, Myanmar, Thailand, Malaysia, Yunnan, Indonesia, the Philippines, Arabia, United Arab Emirates, Saudi Arabia, Oman, New Guinea and northern and eastern Australia (Fleming, 1975; Parsons, 1999; Varshney, Smetacek, 2015)
 Occurrence and status in India: Common
 Host plants of the larvae: *Amaranthus spinosus* L., *A. tricolor* L., *A. viridis* L., *Geissaspis cristata* Wight & Arn., *Oxalis corniculata* L., *Polygonum plebeium* R.Br., *Zornia diphylla* (L.) Pers., *Z. gibbose* Span. (Kunte, 2000; Robinson et al., 2010; Nitin et al., 2018)

Family: Nymphalidae Rafinesque – Brush-footed butterflies

- 12) *Danaus chrysippus* (Linnaeus) – Plain Tiger (Fig. 4B; Fig. 5E form *dorippus* – Appendix 1)
 General range of occurrence: Asia, Australia and Africa (e.g. Madagascar, Seychelles), Southern Europe, Kuwait (Varshney, Smetacek, 2015)

Occurrence and status in India: Very common

Host plants of the larvae: *Asclepias* sp., *Calotropis gigantea* (L.) Dryand., *C. procera* (Aiton) W.T.Aiton, *Cynanchum* sp., *Caralluma adscendens* (Roxb.) R.Br., *Cryptolepis dubia* (Burm.f.) M.R.Almeida, *Hibiscus* sp., *Pergularia daemia* (Forssk.) Chiov. (Kunte, 2000; Robinson et al., 2010. Lovalekar et al., 2018; Nitin et al., 2018)

13) *Junonia hierta* (Fabricius) – Yellow Pansy (Fig. 5A – Appendix 1)

General range of occurrence: Paleoptics (Varshney, Smetacek, 2015)

Occurrence and status in India: Common

Host plants of the larvae: *Asystasia* sp., *Barleria* sp., *Eremomastax* sp., *Hygrophila auriculata* (Schumach.) Heine, *H. costata* Nees, *Justicia* sp., *Mimosa pudica* L., *Ruellia* sp. (Wynter-Blyth, 1957; Kunte, 2000; Robinson et al., 2010)

14) *Junonia lemonias* (Linnaeus) – Lemon Pansy (Fig. 6C – Appendix 1)

General range of occurrence: Cambodia, South Asia (Varshney, Smetacek, 2015)

Occurrence and status in India: Very common

Host plants of the larvae: *Barleria* sp., *Cannabis sativa* L., *Corchorus capsularis* L., *Hygrophila auriculata*, *H. costata*, *Justicia neesii* Ramamoorthy, *J. procumbens* L., *Lepidagathis cuspidate* Nees, *L. keralensis* Madhus. & N.P.Singh, *Nelsonia canescens* (Lam.) Spreng., *Sida rhombifolia* L. (Wynter-Blyth, 1957; Kunte, 2000; Robinson et al., 2010; Nitin et al., 2018)

15) *Junonia orithya* (Linnaeus) – Blue Pansy (Fig. 3A – Appendix 1)

General range of occurrence: Africa, through southern and south-eastern Asia, Australia (Williams, 1994; Varshney, Smetacek, 2015; Westrip, 2022)

Occurrence and status in India: Common

Host plants of the larvae: *Acanthus* sp., *Barleria* sp., *Hygrophila auriculata*, *Justicia micrantha* (Oerst.) V.A.W.Graham, *J. neesii*, *J. procumbens*, *Lepidagathis keralensis*, *L. prostrata* Dalzell *Nelsonia canescens*, *Ruellia tuberosa* L., *Ipomoea batatas* (L.) Lam., *Mimosa pudica*, *Misopates orontium* (L.) Raf., *Plectranthus scandens* (Gürke) R.H.Willemse (Wynter-Blyth, 1957; Kunte, 2000; Robinson et al., 2010)

16) *Tirumala limniace* (Cramer) – Blue Tiger (Fig. 5D – Appendix 1)

General range of occurrence: South Asia, Southeast Asia (Varshney, Smetacek, 2015), Balearic Islands (Truyols-Henares et al., 2019)

Occurrence and status in India: Very common

Host plants of the larvae: *Heterostemma* sp., *Holarrhena pubescens* Wall. & G.Don, *Asclepias curassavica* L., *Calotropis* sp., *Cosmostigma cordatum* (Poir.) M.R.Almeida, *Dregea volubilis* (L.f.) Benth. ex Hook.f., *Hoya* sp., *Marsdenia tenacissima* (Roxb.) Moon, *Saccharum* sp.,

Tylophora indica (Burm.f.) Merr., *Vallis solanacea* Kuntze, (Wynter-Blyth, 1957; Kunte, 2000; Nair, 2002; Robinson et al., 2010; Nitin et al., 2018)

17) *Vanessa cardui* (Linnaeus) – Painted Lady (Fig. 5G – Appendix 1)

General range of occurrence: every continent except Antarctica and South America, Australia (Bunbury, Fremantle, and Rottneest Island) (Varshney, Smetacek, 2015)

Occurrence and status in India: Not-rare, migratory species to India and Least Concern (IUCN, 2023).

Host plants of the larvae: *Althaea* sp., *Anchusa* sp., *Arctotis* sp., *Argemone mexicana* L., *Argyrolobium* sp., *Artemisia vulgaris* L., *Berkheya* sp., *Blumea* sp., *Boehmeria* sp., *Carduus* sp., *Chrysanthemum* sp., *Cirsium arvense* (L.) Scop., *Cynara scolymus* L., *Cynoglossum* sp., *Debregeasia saeneb* (Forssk.) Hepper & J.R.I. Wood, *Dolichos* sp., *Echium* sp., *Filago* sp., *Girardinia diversifolia* (Link) Friis, *Glycine* sp., *Gnaphalium* sp., *Helichrysum* sp., *Lablab purpureus* (L.) Sweet, *Laggera alata* Nanth., *Laportea* sp., *Lupinus* sp., *Madia* sp., *Malva* sp., *Pentzia* sp., *Phaseolus* sp., *Senecio* sp., *Sonchus* sp., *Tricholepis* sp., *Urtica* sp., *Zornia diphylla*, *Z. gibbosa* Span., (Wynter-Blyth, 1957; Kunte, 2000; Robinson et al., 2010; Nitin et al., 2018).

Family: Papilionidae Latreille – Swallowtail butterflies

18) *Pachliopta aristolochiae* (Fabricius) – Common Rose (Fig. 6B – Appendix 1)

General range of occurrence: South Asia, Southeast Asia (Varshney, Smetacek, 2015)

Occurrence and status in India: It is very common almost all over the plains of India, and is not threatened as a species (Kunte, 2000)

Host plants of the larvae: *Aristolochia bracteolata* Lam., *A. griffithii* Hook.f. & Thomson ex Duch., *A. indica* L., *A. tagala* Cham., *Dioscorea wallichii* Hook.f., *Thottea siliquosa* (Lam.) Ding Hou (Wynter-Blyth, 1957; Kunte, 2000; Robinson et al., 2010; Nitin et al., 2018).

19) *Papilio demoleus* (Linnaeus) – Lime Swallowtail (Fig. 5F – Appendix 1)

General range of occurrence: native to Asia and Australia (Varshney, Smetacek, 2015); spread to Hispaniola Island (Dominican Republic) and to Mahé, Seychelles (Guerrero et al., 2004; Kolosova, Bolotov, 2020)

Occurrence and status in India: Common

Host plants of the larvae: *Acronychia pedunculata* Miq., *Aegle marmelos* (L.) Corrêa, *Chloroxylon swietenia* DC., *Citrus aurantiifolia* (Christm.) Swingle, *C. maxima* (Burm.) Merr., *C. sinensis* (L.) Osbeck, *Cullen corylifolium* (L.) Medik., *Glycosmis pentaphylla* (Retz.) DC., *Limonia elephantum* (Corrêa) Panigrahi, *Murraya koenigii* (L.) Spreng., *Ruta angustifolia* Pers., *R. graveolens* L., *Tilia* sp., *Toddalia trifoliata* Druce, *Ziziphus* sp. (Wynter-Blyth, 1957; Kunte, 2000; Robinson et al., 2010).

Family: Pieridae Swainson

20) *Belenois aurota* (Fabricius) – Pioneer (Fig. 3G – Appendix 1)

General range of occurrence: Sri Lanka, India, Persia and Arabia to East Africa (Sub-Saharan Africa) (Varshney, Smetacek, 2015)

Occurrence and status in India: Common, Himalayas from Kashmir to Sikkim at elevations below 6,000 feet (1,800 m), and through the plains to southern India; in the Nilgiris observed up to 8,000 feet (2,400 m) (Varshney, Smetacek, 2015);

Host plants of the larvae: *Boscia* sp., *Capparis* sp.: *C. zeylanica*, *C. pyrifolia* and *Maerua* sp. (Kunte, 2006)

21) *Catopsilia pyranthe* (Linnaeus) – Mottled Emigrant (Fig. 3H – Appendix 1)

General range of occurrence: south Asia, southeast Asia, and parts of Australia (Varshney, Smetacek, 2015)

Occurrence and status in India: Very common

Host plants of the larvae: *Cassia fistula* L., *C. javanica* L., *Gnidia glauca* (Fresen.) Gilg, *Ormocarpum cochinchinense* (Lour.) Merr., *Senna auriculata* (L.) Roxb., *S. obtusifolia* (L.) H.S.Irwin & Barneby, *S. occidentalis* (L.) Link, *S. sophera* (L.) Roxb., *S. sulfurea* (DC. ex Collad.) H.S.Irwin & Barneby, *S. tora* (L.) Roxb., *Sesbania bispinosa* (Jacq.) W.Wight, *S. grandiflora* (L.) Poir., *S. sesban* (L.) Merr. (Wynter-Blyth, 1957; Kunte, 2000, 2006; Robinson et al., 2010)

22) *Colotis amata* (Fabricius) – Small Salmon Arab (Fig. 4F – Appendix 1)

General range of occurrence: Africa, Asia (Varshney, Smetacek, 2015)

Occurrence and status in India: Common in lower altitude and drier landscapes

Host plants of the larvae: *Azima tetracantha* Lam., *Salvadora oleoides* Decne, *S. persica* L. (Wynter-Blyth, 1957; Robinson et al., 2010)

23) *Colotis etrida* (Boisduval) – Little Orange-tip (Fig. 4E – Appendix 1)

General range of occurrence: native to India, Sri Lanka and Pakistan (Perveen et al., 2014; Varshney, Smetacek, 2015).

Occurrence and status in India: Common in lower altitude

Host plants of the larvae: *Cadaba fruticose* Druce, *Maerua oblongifolia* A.Rich., *Salvadora persica* (Wynter-Blyth, 1957; Kunte, 2000; Nitin et al., 2018)

24) *Colotis fausta* (Olivier) – Large Salmon Arab (Fig. 5H – Appendix 1)

General range of occurrence: Israel, Syria, Turkey, Iran, Afghanistan, Turkmenistan, India, Arabia, Chad, Somalia, United Arab Emirates (Varshney, Smetacek, 2015)

Occurrence and status in India: Common in lower altitude

Host plants of the larvae: *Capparis spinosa* L., *Maerua cylindrocarpa* Hadj-Moust., *M. oblongifolia* (Wynter-Blyth, 1957; Robinson et al., 2010)

- 25) *Colotis vestalis* (Butler) – White Arab (Fig. 4H – Appendix 1)
 General range of occurrence: India, Pakistan, Iran, Somalia, Ethiopia, Sudan, Kenya and Tanzania (Bingham, 1907)
 Occurrence and status in India: Western India (Kutch; Rajasthan; Sindh and Madhya Pradesh, south to parts of Northern Karnataka and Telangana) (Wynter-Blyth, 1957)
 Host plants of the larvae: *Salvadora persica* L. (Wynter-Blyth, 1957; Robinson et al., 2010)
- 26) *Eurema hecabe* (Linnaeus) – Common Grass Yellow (Fig. 6A – Appendix 1)
 General range of occurrence: Asia, Africa and Australia (Woodhall, 2005; Varshney, Smetacek, 2015)
 Occurrence and status in India: Very common
 Host plants of the larvae: *Acacia* sp., *Aeschynomene americana* L., *Albizia procera* (Roxb.) Benth., *A. saman* (Jacq.) Merr., *Caesalpinia mimosoides* (Lam.) Gagnon & G.P.Lewis, *C. pulcherrima* (L.) Sw., *C. sappan* L., *Cassia fistula* L., *Mimosa pudica*, *Moullava spicata* (Dalzell ex Wight) Nicolson, *Peltophorum pterocarpum* (DC.) Backer ex K.Heyne, *Pithecellobium dulce* (Roxb.) Benth., *Senna alata*, *S. obtusifolia*, *S. tora*, *Sesbania bispinosa*, *S. grandiflora*, *S. sesban*, *Smithia conferta* Sm., *Smithia sensitiva* Aiton (Wynter-Blyth, 1957; Kunte, 2000; Robinson et al., 2010; Nitin et al., 2018)

Short discussion

Tephrosia purpurea subsp. *purpurea* and *T. p.* subsp. *apollinea* are a great source of nectar and support the life of many butterflies in the Indian Desert, which could be observed during the research carried out here. The selected study locations in Jodhpur district are pesticide-free, but these plants are facing heavy dust due to seasonal sand storms. However, both of these taxa are well adapted to this, what does not prevent them from growing and developing normally (Singh, 1987).

Among the identified butterflies, *Danaus chrysippus* is the most common sighted, observed on *T. purpurea* with a large number of individuals. The activity and the number of individuals of this butterfly are very high between July and August. Black Drongo (*Dicrurus macrocercus* Viillot, 1817) and White-browed Fantail (*Rhipidura aureola* Lesson, 1831) birds often feed on the *D. chrysippus* butterflies. This taxon is not classified by the IUCN. According to some authors, this species includes three subspecies (or forms): *D. c. chrysippus* (Linnaeus, 1758), *D. c. alcippus* (Cramer, 1777) and *D. c. orientis* (Aurivillius, 1909) (Smith et al., 2005). According to these authors, *D. c. dorippus* (Fig. 5E – Appendix 1) deserved to be distinguished as a separate species. However, in 2010 this subspecies was again included among the subspecies of *D. c. chrysippus*. Braby et al. (2015) questioned the certainty with which the all subspecies of this butterfly were classified.

Other species, *Vanessa cardui* (Fig. 5G – Appendix 1) is the rarely sighted butterfly in the study area. On a national scale, it is classified as Least Concern, not-rare, migratory species to India (Varshney, Smetacek, 2015). Typical biotopes of this butterfly are ruderal areas, gardens, field margins, fallow fields, and roadsides. It avoids forests because it prefers open places. Painted lady migration patterns are highly erratic and they do not migrate every year (Larsen, 1984). Some evidence suggests that global climatic events, such as *el Niño*, may affect the migratory behaviour of the *V. cardui*, causing large-scale migrations (Tilden, 1962).

Compared to all other butterflies noticed, *Tarucus nara* (Fig. 4G – Appendix 1) frequently appeared through the study duration, and *Pachliopta aristolochiae* (Fig. 6B – Appendix 1) appeared at few locations especially near human settlements. The last of these species, is very common almost all over the plains of India, and is not threatened as a species. During and after the monsoon *P. aristolochiae* is extremely abundant. As an excellent generalist species, it has adapted to a range of habitats, including desert ones. The butterfly is a common visitor to Indian gardens and can even be found in crowded urban areas (Munshi, Moiz, 1970; Varshney, Smetacek, 2015).

The butterflies that collect nectar from the *Tephrosia purpurea* subsp. *purpurea* and *T. p.* subsp. *apollinea* also visit the agriculture and horticulture plants in and around the arid zones of Jodhpur, promoting cross-pollination. We found 8 butterflies of the Lycaenidae (blues) family and these also collect the moisture (dew) from the inflorescence of grass and help in the cross-pollination of millets. All recorded species of butterflies are also collect nectar from the other plant species associated with the desert of Jodhpur. Many plants growing in the vicinity that are visited by recorded butterflies act as host plants for the butterfly larvae. For example, *Calotropis procera*, which is common here, is a host plant for the larvae of *Danaus chrysippus*, *Tirumala limniace*, and species of the genus *Indigofera* for the larvae of *Freyeria putli*, *Leptotes plinius* (Tab. 1 – Appendix 2).

According to research, analysed plants are a source of food for butterflies and their larvae, but not only. Other insects, such as honey bees (*Apis cerana indica* Fabricius, 1798, *A. dorsata* Fabricius, 1793) also benefit from the nectar of these plants. The flowers of these taxa are numerous and have nectar tags that attract insects (Fig. 1). Therefore, there is a system of close relationships between many species of both plants and pollinating insects, that occur here.

The analysed plant taxa constitute an important element of the landscape of Jodhpur district. Our study strongly suggests the planting of *T. purpurea* subsp. *purpurea* and *T. p.* subsp. *apollinea* in butterfly gardens across the country as they withstand higher and lower temperatures, and require less water and maintenance.

Conclusions

[i] The study shows that *Tephrosia purpurea* subsp. *purpurea* and *T. p.* subsp. *apollinea* possesses nectar guides and these specific flowers reduce pollinators time for nectar collection and increase the foraging capacity by reducing the time and energy.

[ii] Among the 26 species of butterflies recorded here, common taxa dominate, but in these unfavourable environmental conditions it is of great importance in maintaining the overall biodiversity of this area. The present study reveals also that chemical-free natural habitats and native plant species will enhance the insect pollinators to maintain the ecosystem balance. This study strongly recommends these plant species for ornamental potential and butterfly gardens in urban areas.

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Conflict of interest

The authors declare no conflict of interest related to this article.

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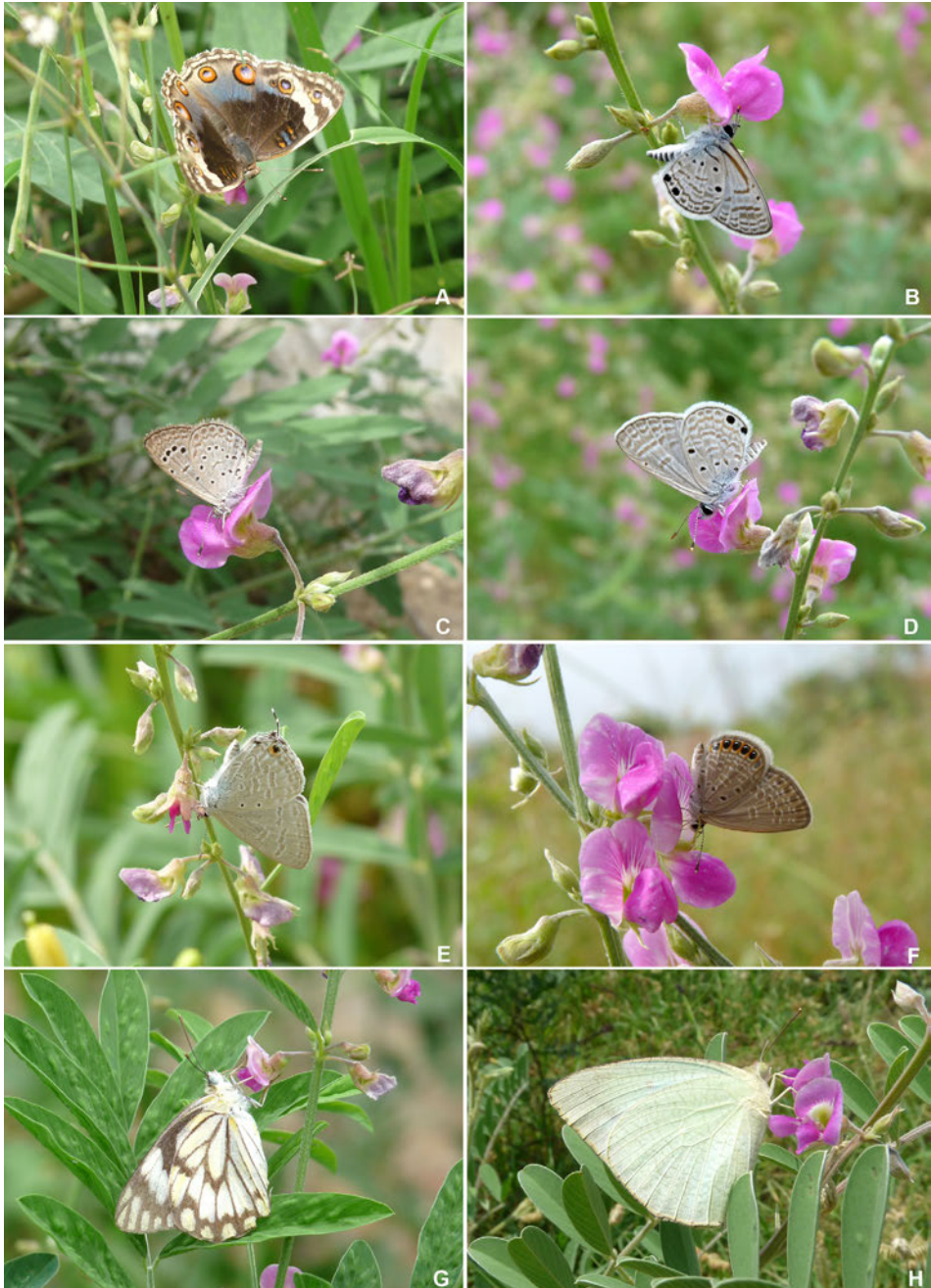


Fig. 3. Butterflies. A. *Junonia orithya* Linnaeus; B. *Azonus ubaldus* Stoll; C. *Zizeeria karsandra* Moore; D. *Azonus uranus* Butler; E. *Catochrysops strabo* Fabricius; F. *Freyeria putli* Kollar; G. *Belenois aurota* Fabricius; H. *Catopsilia pyranthe* L. (Photo. Ravi Kiran Arigela)



Fig. 4. Butterflies. A. *Gegenes pumilio* Hoffmannsegg; B. *Danaus chrysippus* Linnaeus; C. *Chilades pandava* Horsfield; D. *Borbo cinnara* Wallace; E. *Colotis etrida* Boisduval; F. *Colotis amata* Fabricius; G. *Tarucus nara* Kollar; H. *Colotis vestalis* Butler (Photo. Ravi Kiran Arigela)



Fig. 5. Butterflies. A. *Junonia hierta* Fabricius; B. *Leptotes plinius* Fabricius; C. *Spialia galba* Fabricius; D. *Tirumala limniace* Cramer; E. *Danaus chrysippus* Linnaeus form *dorippus*; F. *Papilio demoleus* Linnaeus; G. *Vanessa cardui* Linnaeus; H. *Colotis fausta* Olivier (Photo. Ravi Kiran Arigela)



Fig. 6. Butterflies. A. *Eurema hecabe* Linnaeus.; B. *Pachliopta aristolochiae* Fabricius; C. *Junonia lemonias* Linnaeus. (Photo. Ravi Kiran Arigela)

Tab. 1. A list of desert plants in Jodhpur district which are nectaring too by butterfly species noticed on *T. purpurea* (made by own observations)

No.	Name of plant	Names of nectaring butterflies
1.	<i>Aerva javanica</i>	<i>Azonus uranus</i> , <i>Freyeria putli</i> , <i>Chilades pandava</i> , <i>Leptotes plinius</i>
2.	<i>Arnebia hispidissima</i> .	<i>Freyeria putli</i> , <i>Tarucus nara</i>
3.	<i>Calotropis procera</i>	<i>Tirumala limniace</i> , <i>Danaus chrysippus</i> , <i>Junonia hierta</i>
4.	<i>Cenchrus biflorus</i>	<i>Freyeria putli</i> , <i>Chilades pandava</i> , <i>Leptotes plinius</i>
5.	<i>Cenchrus setigerus</i>	<i>Freyeria putli</i> , <i>Chilades pandava</i> , <i>Tarucus nara</i> , <i>Junonia hierta</i> , <i>Leptotes plinius</i>
6.	<i>Citrullus colocynthis</i>	<i>Spialia galba</i> , <i>Junonia orithya</i> , <i>J. lemonias</i> , <i>J. hierta</i>
7.	<i>Citrullus lanatus</i>	<i>Spialia galba</i> , <i>Junonia orithya</i> , <i>J. hierta</i>
8.	<i>Cleome viscosa</i>	<i>Azonus ubaldus</i> , <i>Eurema hecabe</i> , <i>Leptotes plinius</i>
9.	<i>Clerodendrum phlomidis</i>	<i>Tirumala limniace</i> , <i>Chilades pandava</i> , <i>Danaus chrysippus</i> , <i>Junonia hierta</i>
10.	<i>Convolvulus prostratus</i>	<i>Junonia orithya</i> , <i>Chilades pandava</i> , <i>Colotis etrida</i> , <i>Leptotes plinius</i>
11.	<i>Corchorus depressus</i> .	<i>Freyeria putli</i> , <i>Tarucus nara</i>
12.	<i>Crotalaria burhia</i>	<i>Junonia orithya</i> , <i>Chilades pandava</i> , <i>Tarucus nara</i> , <i>Junonia hierta</i>
13.	<i>Echinops echinatus</i>	<i>Tirumala limniace</i> , <i>Danaus chrysippus</i> , <i>Papilio demoleus</i>
14.	<i>Indigofera cordifolia</i>	<i>Spialia galba</i> , <i>Zizeeria karsandra</i> , <i>Azonus uranus</i> , <i>Freyeria putli</i> , <i>Chilades pandava</i> , <i>Tarucus nara</i> , <i>Leptotes plinius</i>
15.	<i>Indigofera. hochstetteri</i>	<i>Spialia galba</i> , <i>Zizeeria karsandra</i> , <i>Azonus uranus</i> , <i>Freyeria putli</i> , <i>Chilades pandava</i> , <i>Tarucus nara</i> , <i>Leptotes plinius</i>
16.	<i>Indigofera linifolia</i>	<i>Spialia galba</i> , <i>Zizeeria karsandra</i> , <i>Catochrysops strabo</i> , <i>Freyeria putli</i> , <i>Chilades pandava</i> , <i>Tarucus nara</i> , <i>Leptotes plinius</i>
17.	<i>Indigofera. trita</i>	<i>Spialia galba</i> , <i>Zizeeria karsandra</i> , <i>Freyeria putli</i> , <i>Chilades pandava</i> , <i>Tarucus nara</i> , <i>Leptotes plinius</i>
18.	<i>Indigofera. tsiangiana</i>	<i>Spialia galba</i> , <i>Zizeeria karsandra</i> , <i>Catochrysops strabo</i> , <i>Freyeria putli</i> , <i>Chilades pandava</i> , <i>Tarucus nara</i> , <i>Leptotes plinius</i>
19.	<i>Lantana camara</i>	<i>Tirumala limniace</i> , <i>Catopsilia pyranthe</i> , <i>Danaus chrysippus</i> , <i>Chilades pandava</i> , <i>Gegenes pumilio</i> , <i>Borbo cinnara</i> , <i>Tarucus nara</i> , <i>Leptotes plinius</i>
20.	<i>Lasiurus scindicus</i>	<i>Eurema hecabe</i> , <i>Belenois aurota</i> , <i>Tarucus nara</i>
21.	<i>Launaea procumbens</i>	<i>Spialia galba</i> , <i>Zizeeria karsandra</i> , <i>Azonus uranus</i> , <i>Catochrysops strabo</i> , <i>Freyeria putli</i> , <i>Chilades pandava</i> , <i>Tarucus nara</i> , <i>Leptotes plinius</i>
22.	<i>Leptadenia pyrotechnica</i>	<i>Zizeeria karsandra</i> , <i>Azonus uranus</i> , <i>Freyeria putli</i> , <i>Tarucus nara</i>
23.	<i>Lycium edgeworthii</i>	<i>Spialia galba</i> , <i>Zizeeria karsandra</i> , <i>Azonus uranus</i> , <i>Catochrysops strabo</i> , <i>Freyeria putli</i> , <i>Chilades pandava</i> , <i>Tarucus nara</i> , <i>Junonia hierta</i> , <i>Leptotes plinius</i>

24.	<i>Momordica balsamina</i>	<i>Junonia hierta</i> , <i>J. orithya</i> , <i>J. lemonias</i> , <i>Borbo cinnara</i>
25.	<i>Pavonia zeylonica</i>	<i>Tirumala limniace</i> , <i>Papilio demoleus</i> , <i>Danaus chrysippus</i> , <i>Colotis amata</i> , <i>C. etrida</i> , <i>C. vestalis</i>
26.	<i>Pergularia daemia</i>	<i>Tirumala limniace</i> , <i>Danaus chrysippus</i> , <i>Junonia hierta</i>
27.	<i>Prosopis cineraria</i>	<i>Spialia galba</i> , <i>Zizeeria karsandra</i> , <i>Azonus uranus</i> , <i>Catochrysops strabo</i> , <i>Freyeria putli</i> , <i>Chilades pandava</i> , <i>Tarucus nara</i> , <i>Leptotes plinius</i>
28.	<i>Pulicaria angustifolia</i>	<i>Junonia orithya</i> , <i>Zizeeria karsandra</i> , <i>Azonus uranus</i> , <i>Catochrysops strabo</i> , <i>Freyeria putli</i> , <i>Chilades pandava</i> , <i>Gegenes pumilio</i> , <i>Borbo cinnara</i> , <i>Tarucus nara</i> , <i>Leptotes plinius</i>
29.	<i>Rostellularia quinqueangularis</i>	<i>Zizeeria karsandra</i> , <i>Azonus uranus</i> , <i>Catochrysops strabo</i> , <i>Freyeria putli</i> , <i>Chilades pandava</i> , <i>Tarucus nara</i> , <i>Leptotes plinius</i>
30.	<i>Senna alexandrina</i>	<i>Spialia galba</i> , <i>Zizeeria karsandra</i> , <i>Azonus uranus</i> , <i>Catochrysops strabo</i> , <i>Freyeria putli</i> , <i>Chilades pandava</i> , <i>Danaus chrysippus</i> , <i>Tarucus nara</i> , <i>Leptotes plinius</i>
31.	<i>Sida tiagii</i>	<i>Junonia hierta</i> , <i>J. orithya</i> , <i>Papilio demoleus</i> , <i>Colotis fausta</i> , <i>C. vestalis</i> , <i>Tarucus nara</i> , <i>Leptotes plinius</i> .
32.	<i>Solanum virginianum</i>	<i>Catochrysops strabo</i> , <i>Junonia orithya</i> , <i>Chilades pandava</i> , <i>Danaus chrysippus</i> , <i>Junonia hierta</i>
33.	<i>Tecomella undulata</i>	<i>Tirumala limniace</i> , <i>Danaus chrysippus</i> , <i>Borbo cinnara</i>
34.	<i>Tribulus terrestris</i>	<i>Spialia galba</i> , <i>Zizeeria karsandra</i> , <i>Azonus uranus</i> , <i>Catochrysops strabo</i> , <i>Freyeria putli</i> , <i>Chilades pandava</i>
35.	<i>Tridax procumbens</i>	<i>Spialia galba</i> , <i>Zizeeria karsandra</i> , <i>Azonus uranus</i> , <i>Catochrysops strabo</i> , <i>Freyeria putli</i> , <i>Chilades pandava</i> , <i>Danaus chrysippus</i> , <i>Tarucus nara</i> , <i>Leptotes plinius</i>
36.	<i>Vachellia tortilis</i>	<i>Zizeeria karsandra</i> , <i>Azonus uranus</i> , <i>Catochrysops strabo</i> , <i>Freyeria putli</i> , <i>Chilades pandava</i> , <i>Danaus chrysippus</i> , <i>Tarucus nara</i> , <i>Leptotes plinius</i>
37.	<i>Zygophyllum indicum</i>	<i>Tirumala limniace</i> , <i>Catopsilia pyranthe</i> , <i>Belenois aurota</i> , <i>Danaus chrysippus</i> , <i>Tarucus nara</i>

Tephrosia purpurea, potencjalne źródła nektaru dla motyli w Jodhpur, suchej strefie pustyni Thar w Radżastanie (Indie)

Streszczenie

Obserwacje interakcji roślina-owad, poparte dowodami fotograficznymi, zostały przeprowadzone w skrajnie suchej strefie pustyni Thar w Radżastanie w Jodhpur (Indie). Badania dotyczyły taksonów roślin: *Tephrosia purpurea* subsp. *purpurea* i *T. purpurea* subsp. *apollinea*, należących do rodziny bobowatych (Fabaceae). Odnotowano tu łącznie 26 gatunków motyli przynależnych do rodzin Hesperidae (Powszelatkowate), Lycaenidae (Modraszkwate), Nymphalidae (Rusałkowate), Papilionidae (Paziowate) i Pieridae (Bielninkowate). Stwierdzono, że te dwie rośliny są głównym źródłem nektaru, stanowiącym część diety i są roślinami żywicielskimi dla larw motyli. Odnotowane motyle odwiedzają na badanym terenie również inne gatunki roślin pustynnych. Obserwacje te wyjaśniają znaczenie tych dwóch rodzimych taksonów roślin dla ochrony zapylaczy w suchych strefach kraju.

Słowa kluczowe: Różnorodność biologiczna, zapylanie krzyżowe, środowisko, kwiaty, przewodnicy po nektarach, zapylacze

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